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REC'D 11 JUN 2003
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1) South African Patent Application No. **2002/2513** accompanied by a Provisional Specification was filed at the South African Patent Office on the **28 March 2002**, in the name of **SMI Technology (PTY) LIMITED** in respect of an invention entitled: **"System and method for monitoring features of a blast"**

2) The photocopy attached hereto is a true copy of the provisional specification and drawings filed with South African Patent Application No. **2002/2513.**

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Geteken te PRETORIA in die Republiek van Suid-Afrika, hierdie 15th dag van April 2003
Signed at PRETORIA in the Republic of South Africa, this 15th day of **April 2003**

Registrateur van Patente
Registrar of Patents

Form P.2

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PATENTS ACT, 1978

REGISTER OF PATENTS

FICIAL APPLICATION NO.	LODGING DATE : PROVISIONAL	ACCEPTANCE DATE
01 2002/2513	22 28 March 2002	43
ERNATIONAL CLASSIFICATION	LODGING DATE : COMPLETE	GRANTED DATE
	23	

JLL NAME(S) OF APPLICANT(S) / PATENTEE(S)

SMI TECHNOLOGY (PTY) LIMITED

PLICANTS SUBSTITUTED :	DATE REGISTERED

SSIGNEE(S)	DATE REGISTERED

JLL NAME(S) OF INVENTOR(S)

MEYER, Erich Nicol

LOWNDS, Charles Michael

RIORITY CLAIMED	COUNTRY	NUMBER	DATE
.B. Use international obreviation for country. See Schedule 4)	33	31	32

ITLE OF INVENTION

4 SYSTEM AND METHOD FOR MONITORING FEATURES OF A BLAST

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PATENT OF ADDITION NO.	DATE OF ANY CHANGE
61	
FRESH APPLICATION BASED ON	DATE OF ANY CHANGE

Form P.1

EPUBLIC OF SOUTH AFRICA
ATENTS ACT, 1978

PPLICATION FOR A PATENT AND ACKNOWLEDGEMENT OF RECEIPT
Section 30 (1) - Regulation 22)
he grant of a patent is hereby requested by the undermentioned applicant
n the basis of the present application filed in duplicate.

OFFICIAL APPLICATION NO			DMK REFERENCE
21	01	2002/2513	P24037ZA00

FULL NAME(S) OF APPLICANT(S)

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TITLE OF INVENTION

54 SYSTEM AND METHOD FOR MONITORING FEATURES OF A BLAST

THE APPLICANT CLAIMS PRIORITY AS SET OUT ON THE ACCOMPANING FORM P2
The earliest priority claimed is

THIS APPLICATION IS FOR A PATENT OF ADDITION TO PATENT APPLICATION NO.	21	01	
THIS APPLICATION IS FRESH APPLICATION IN TERMS OF SECTION 37 AND BASED ON APPLICATION NO.	21	01	

THIS APPLICATION IS ACCOMPANIED BY :

x	1a	A single copy of a provisional specification of 18 pages.
	1b	Two copies of a complete specification of pages.
	2a	Informal drawings of sheets.
x	2b	Formal drawings of 8 sheets.
	3	Publication particulars and abstract (form P8 in duplicate).
	4	A copy of figure of the drawings for the abstract.
	5	Assignment of invention (from the inventors) or other evidence of title.
	6	Certfied priority document(s).
	7	Translation of priority document(s).
	8	Assignment of priority rights.
	9	A copy of form P2 and a specification of S.A. Patent Application. 21 01
	10	A declaration and power of attorney on form P3.
	11	Request for ante-dating on form P4.
	12	Request for classification on form P9.
	13a	Request for delay of acceptance on form P4.
	13b	

DATED 28 March 2002

Patent Attorney for Applicant(s)

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OFFICIAL DATE STAMP

REGISTRAR OF PATENTS

The duplicate will be returned to the applicant's address for service as proof of lodging but is not valid unless endorsed with official stamp.

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PROVISIONAL SPECIFICATION

(Section 30 (1) - Regulation 27)

OFFICIAL APPLICATION NO.			LODGING DATE		DMK REFERENCE
21	01	2002/2313	22	28 March 2002	P24037ZA00

FULL NAME(S) OF APPLICANT(S)	
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FULL NAME(S) OF INVENTOR(S)	
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TITLE OF INVENTION	
54	SYSTEM AND METHOD FOR MONITORING FEATURES OF A BLAST

INTRODUCTION AND BACKGROUND TO THE INVENTION

This invention relates to blasting systems and more particularly to a method and system for monitoring features of a blast, for example velocity of detonation of a main charge.

Rock (and soil) blasting is usually achieved by drilling an array of boreholes, placing in each an initiation device or detonator, and partially filling or stemming the holes with explosives. The initiation devices are selected and interconnected so as to allow the explosive charges in the holes to be detonated by the initiation devices in a desired sequence. There are several features or parameters associated with detonation of an explosive in rock which are of potential interest, including the time instant of detonation, the velocity of the detonation wave, pressures in the detonating explosive, time of arrival and intensity of shock pressure at an adjacent hole, vertical length of the stemming in the hole, the acceleration history of the burden, ground vibration etc. Detonation velocity is one of the most commonly measured dynamic features of blasting and therefore various methods and systems for monitoring or measuring the velocity of detonation of a main charge are known. In one known approach, a special monitoring circuit is deployed with dedicated conductors extending into the blast holes. The special circuit is energised by a suitable signal generated at a remote site and parameters of the signal during the blast are monitored to ascertain the velocity of detonation. Since blasting is a violent event, the signal

generation and monitoring devices in this known method are kept at a significant distance from the holes in which the measurements are being done, and are connected to the measuring circuitry by long electrical cables. It will be appreciated that this special and dedicated circuit is contributing to the cost of the system as well as to labour and time to prepare the blast site.

OBJECT OF THE INVENTION

Accordingly it is an object of the present invention to provide an alternative method and system with which the applicants believe the aforementioned disadvantages may at least be alleviated.

SUMMARY OF THE INVENTION

According to the invention there is provided a method of monitoring at least one feature of a blast, the method comprising the steps of:

- providing at least one detonator at a blast site to cause at least part of the blast;
- prior to the blast, utilizing a data communication path extending between a blast controller and the at least one detonator, to communicate blast control signals to the at least one detonator;
- during a period following start of the blast, utilizing a blast feature signal communication path comprising at least part of the data communication path to communicate a blast feature signal

relating to at least one feature of the blast to a blast feature monitoring station, which is remote from any blast activity.

In a preferred form of the method, a plurality of detonators are provided in spaced relation at the blast site.

The feature may be velocity of detonation (VOD) of a main charge initiated by the detonator. In a single-shot blast, other features that may be monitored are: time instant of start of detonation, ground vibrations, detonation or explosion pressure in a blast hole and length or depth of the main charge in the blast hole. In a multiple-shot blast, the feature may be any one of the aforementioned plus shock pressure caused by detonation in an adjacent hole, delay time between start of detonations in adjacent holes, to name but a few.

The blast controller and the blast feature monitoring station may be provided at a common location which is remote from the blast site.

The data communication path may comprise respective conductor arrangements connected to each of said detonators. The respective conductor arrangements may branch from a main conductor arrangement connected to the blast controller.

In some forms of the method, the blast feature signal may be generated by at least one transducer which is connected to one of the main conductor arrangement and any of the respective conductor arrangements. The at least one transducer is preferably located outside of any detonator housing. The transducer may generate a blast feature signal in response to pressure, acceleration, strain or any other feature of the blast.

The blast feature signal generated by the at least one transducer may be transmitted to the blast feature monitoring station via the blast feature signal communication path comprising at least part of the main conductor arrangement. Alternatively, the blast feature signal communication path may comprise at least part of a conductor arrangement to which the at least one transducer is connected and a wireless ink.

Other forms of the method may comprise the steps of generating a monitoring signal in a respective conductor arrangement and sensing a change in a parameter of the signal as a result of the blast, to provide the blast feature signal.

The monitoring signal may comprise a first signal and a derivative signal, such as a reflection of the first signal on the conductor. The parameter may relate to a difference in corresponding parameters between the first signal

and the derivative signal, such as a difference in phase, amplitude and frequency.

Hence, the method may comprise the steps of causing a signal generator to generate a first signal for propagation on the respective conductor arrangement to cause a reflection of the first signal, and monitoring changes in a phase and/or amplitude difference between the first signal and the reflection before, during and immediately after detonation.

The first signal may be generated by a signal generator located at the remote blast controller and which is connected to said respective conductor arrangement by said main conductor arrangement.

Alternatively, the first signal may be generated in the respective conductor arrangement by a signal generator located at the remote blast controller and data relating to the change may be transmitted from a sensor connected to the respective conductor arrangement via a wireless link to the remote feature monitoring station.

Further alternatively, the first signal is generated by a signal generator connected directly to the respective conductor arrangement and data relating to the change is transmitted by a sensor connected to the

conductor arrangement via a wireless link to the remote feature monitoring station.

According to another aspect of the invention, a system for monitoring at least one feature of a blast comprises:

- at least one detonator located at a blast site to cause at least part of the blast;
- a data communication path extending between a blast controller and the at least one detonator, to communicate blast control signals to the at least one detonator;
- a transducer sensitive to a feature of the blast which is located outside of a housing of the at least one detonator and connected to the data communication path, so that a blast feature signal relating to the feature of the blast may be transmitted from the transducer to a remote blast feature monitoring station via a blast feature signal communication path comprising at least part of the data communication path.

The transducer may comprise a separate device connected to a conductor arrangement which is connected to the detonator. In other embodiments, the transducer may comprise said conductor arrangement connected to the detonator.

According to yet another aspect of the invention there is provided a method of monitoring a feature of a blast, the method comprising the steps of:

- providing a conductor arrangement connected to a detonator and which detonator causes part of the blast;
- generating a monitoring signal in the conductor arrangement;
- sensing a change in a parameter of the signal as a result of the blast; and
- processing data relating to the change for providing data relating to the feature.

The feature may be velocity of detonation (VOD) of a main charge initiated by the detonator and at least part of the conductor arrangement may be embedded in the main charge.

The conductor arrangement may be connected to the detonator to control the detonator, for example by transmitting at least one of programming data, a fire signal and power to the detonator from a remote source, such as a blast controller. The conductor arrangement may comprise a pair of twisted conductors.

The monitoring signal may comprise a first signal and a derivative signal, such as a reflection of the first signal on the conductor. The parameter may

relate to a difference in corresponding parameters between the first signal and the derivative signal, such as a difference in phase, amplitude and frequency.

A presently preferred form of the method comprises the steps of causing a signal generator to generate a first signal for propagation on the conductor arrangement to cause a reflection of the first signal, and monitoring changes in a phase and/or amplitude difference between the first signal and the reflection before, during and immediately after detonation.

In a first form of the method, the first signal may be generated by a signal generator at a remote blast controller which is connected to said conductor arrangement by a main conductor arrangement.

In a second form of the method, the first signal is generated by a signal generator at the remote blast controller and data relating to the change is transmitted from a sensor connected to the conductor arrangement via a wireless link to a remote feature monitoring and data processing station.

In a third form of the method, the first signal is generated by a signal generator connected directly to the conductor arrangement and data relating to the change is transmitted by a sensor connected to the

conductor arrangement via a wireless link to a remote feature monitoring and data processing station.

According to still another aspect of the invention there is provided a system for monitoring a feature of a blast, the system comprising:

- a detonator for causing at least part of the blast;
- a conductor arrangement connected to the detonator for controlling operation of the detonator;
- a monitoring signal generator arranged to generate a monitoring signal in the conductor arrangement; and
- a circuit for sensing changes in a parameter of the monitoring signal as a result of the blast.

In a first embodiment of the system the signal generator is connected to the conductor arrangement by a main conductor arrangement extending between the conductor arrangement and the signal generator.

The signal generator may form part of or be connectable to a blast controller.

The sensing circuit may also form part of or be connected to the blast controller.

In a second embodiment the sensing circuit is connected directly to the conductor arrangement and data relating to the changes may be transmitted by the sensing circuit via a wireless link to a remote feature monitoring and data processing system.

The sensing circuit may be connected to the main conductor arrangement at a point where the main conductor arrangement branches into the conductor arrangement.

In a third embodiment the signal generator and the sensing circuit are connected directly to the conductor arrangement and a wireless link between the sensing circuit and a remote feature monitoring and data processing system enables the sensing circuit to transmit the data relating to changes in the parameter to the remote system.

The conductor arrangement and the main conductor arrangement may comprise a pair of twisted conductors.

The wireless link may comprise an RF transceiver at both ends hereof.

BRIEF DESCRIPTION OF THE ACCOMPANYING DIAGRAMS

The invention will now further be described, by way of example only, with reference to the accompanying diagrams wherein:

figure 1	is a block diagram of a first embodiment of a detonation system comprising a blast feature monitoring system according to the invention in the form of a VOD measurement system;
figure 2	is a block diagram of a second embodiment of the system according to the invention;
figure 3	is a block diagram of a third embodiment of the system according to the invention;
figure 4	is a basic block diagram of part of a VOD measurement system;
figure 5	depicts waveforms measured at points A and B in figure 4, before detonation of a main charge;
figure 6	depicts similar waveforms during a period from before detonation, during detonation until after the detonation;
figure 7	depicts similar waveforms on a smaller time scale during the detonation; and
figure 8	depicts similar waveforms also on the smaller time scale, but towards the end of the detonation.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

In figure 1 there is shown a block diagram of a first embodiment of a detonation system comprising a blast feature monitoring system according

to the invention in the form of a velocity of detonation (VOD) measurement system designated by the reference numeral 10.

The system is shown deployed at a blast site 12 defining a plurality of blast holes 14.1 to 14.n. In each of the holes there is provided an electric, alternatively and electronic detonator 16.1 to 16.n respectively. Each detonator 16.1 to 16.n is connected via a respective branch or "down the hole" lead conductor arrangement 18.1 to 18.n to main lead conductor arrangement 20 which in turn is connected to a blast controller 22. Each lead conductor arrangement 20 and 18.1 to 18.n preferably comprises a known twisted pair of conductors.

Each of holes 14.1 to 14.n is stemmed with a respective body 24.1 to 24.n of a main charge. The conductor arrangements 18.1 to 18.n are at least partially embedded in respective bodies 24.1 to 24.n. The body of main charge may comprise any one or more of known emulsion explosives, ANFO, blends thereof, nitroglycerin and watergell explosives. It is known that once a main charge is detonated by the detonator 16.1 in known manner, the detonation propagates in the body of main charge as shown at C. The speed of propagation is referred to as the velocity of detonation (VOD) and is measured in meters per second or feet per second.

In use, the detonators 16.1 to 16.n are programmed by blast controller 22 in known manner by transmitting programming data, such as delay time data, on conductor arrangements 20 and 18.1 to 18.n. Power is also transmitted to the detonators to be stored on respective local charge storage devices (not shown). A common "fire"-signal is then transmitted on the aforementioned conductor arrangements. Upon receipt of the "fire"-signal, and also in known manner, each detonator starts to process respective delay time data. At the end of a respective delay time, a fuse in the detonator is energized by charge stored on the charge storage device, to cause detonation. As stated hereinbefore, the detonation propagates as shown at C and in the process disintegrates at least part of the respective branch conductor arrangement 18.1.

A VOD measurement system 26 according to the invention utilizes changes in one or more parameters of a monitoring signal transmitted on the conductor arrangements 20 and 18.1 to 18.n acting as blast feature transducer, to determine the VOD, as will hereafter be described. Such parameters may include phase, amplitude, frequency etc or changes in differences between values of these parameters of a first signal and a derivative signal, such as a reflection of the first signal on the conductor arrangement.

In figure 4 there is shown a block diagram of part of one example of a VOD measurement system 24 falling within the scope of the present invention. The system comprises a monitoring signal generator 26 which is connected to the main lead conductor arrangement 20. The monitoring signal is sensed at point A and connected via suitable circuitry 28 to a waveform recorder in the form of an oscilloscope 30, for example. Signals on line 20 are sensed at point B and fed via circuitry 32 to the recorder 30. In the recorder, resulting signals are reproduced for comparison and analysis. This comparison and analysis may be computerized and may yield output data relating to various aspects of a blast, including VOD.

In figure 5 there are shown typical waveforms at points A and B before detonation. As will be clear, the monitoring signal at A is in the form of a sine wave having a frequency of about 150kHz. The second signal at point B represents a reflection on the conductor arrangements. It will be seen that there is an initial phase difference $\Delta\emptyset_1$ between the two signals as well as an initial amplitude difference ΔA_1. It has been found that these differences are proportional to the length of the conductor arrangements 18.1 and 20. It has also been found that for the conductor arrangements used in an experiment, a phase difference of 15 – 20 degrees represents a length of about 30 meters.

In figure 6, there are shown the waveforms at A and B, before, during and after the detonation. Start of detonation is shown at point 36 and end of detonation is shown at point 38. The detonation propagates through the charge body during period 34, as hereinbefore described.

In figure 7 there are shown the signals at A and B during part of period 34, but on a smaller time base. A change in amplitude of the signal at B is clearly visible as is a charge in the aforementioned initial phase difference $\Delta\varnothing_1$.

In figure 8 there are shown the waveforms at A and B towards the end of period 34 and after the end of detonation at point 38.

After point 38, the phase difference is $\Delta\varnothing_2$ and which has been determined to indicate a conductor arrangement length of 28 meters. The time period 34 of detonation is determined at 240 μs. Similar measurements for the length of the conductor arrangements may be made on the bases of changes in the difference between the amplitudes $\Delta A_2 - \Delta A_1$.

The VOD is determined by:

$$= \frac{\text{change in conductor arrangement length}}{\text{time period 34}}$$

$$= \frac{2\text{m}}{240\mu\text{s}}$$

$$= 8333 \text{ m/s}$$

In figure 2 there is shown another embodiment of the VOD measurement system according to the invention. In this embodiment data relating to signals at points A and B propagating in conductor arrangement 18.1 is transmitted via a wireless link 40.1 by sensor 42 connected to conductor arrangement 18.1 to VOD data processing system 44. Similarly data relating to corresponding signals at A and B on conductor arrangement 18.2 is transmitted by sensor 46 via wireless link 40.2 to the VOD data processing system 44.

In figure 3 there is shown a system wherein main lead conductor arrangement 20 for conveying programming data, power and the "fire"-signal to the detonators 16.1 to 16.n is replaced by a wireless system. As in the case of the system in figure 2, data relating to the signals at A and B propagating in conductor arrangement 18.1 is transmitted via a wireless link 50 by sensor 52 connected to conductor arrangement 18.1 to VOD data processing system 44. The monitoring signal may be generated by a signal generator (not shown) forming part of sensor 42.

It will be appreciated that other aspects of a blast or shots in a multi shot blast may also be monitored and/or measured by utilizing parameters and changes in parameters of a monitoring signal. Such aspects include: time instant of start of detonation, shock pressure from detonation in adjacent

hole, ground vibrations, detonation or exploration pressure in a hole, delay between detonations in adjacent holes, length of main charge body, etc.

In other embodiments a separate transducer located outside the housing of any detonator may be utilized to generate the blast feature signal. In these embodiments the transducer is connected to the main conductor arrangement 20 or to a respective branch conductor arrangements 18.1 to 18.1n, so that a blast feature signal communication path for transmitting the blast feature signal to a remote blast feature monitoring station, such as VOD measurement system 26, comprises at least part of a data communication path 20, 18.1 to 18.n extending between the blast controller 22 and the detonators.

It will further be appreciated that many variations in detail are possible on the system and method according to the invention without departing from the scope and spirit of this disclosure.

Dated this 28 day of March 2002

Patent Attorney / Agent for the Applicant

2002/2513

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8 Sheets
Sheet 1

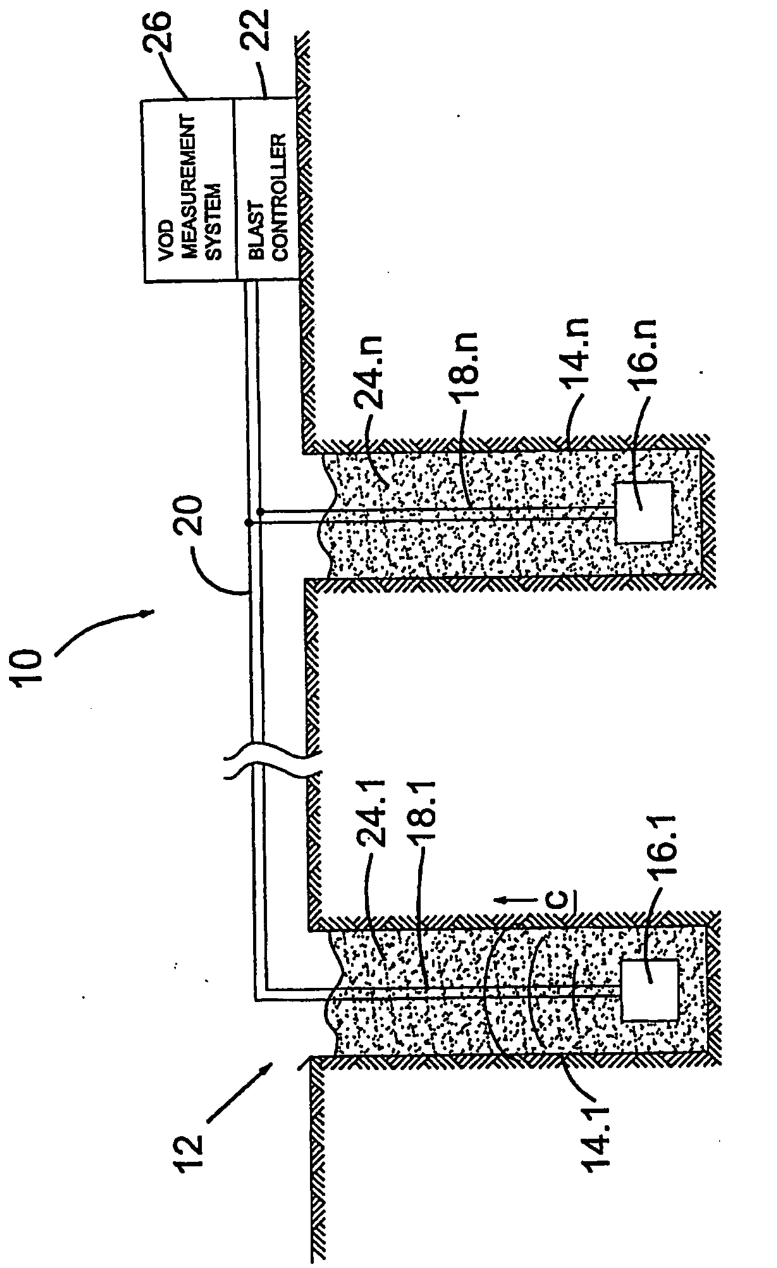

FIGURE 1

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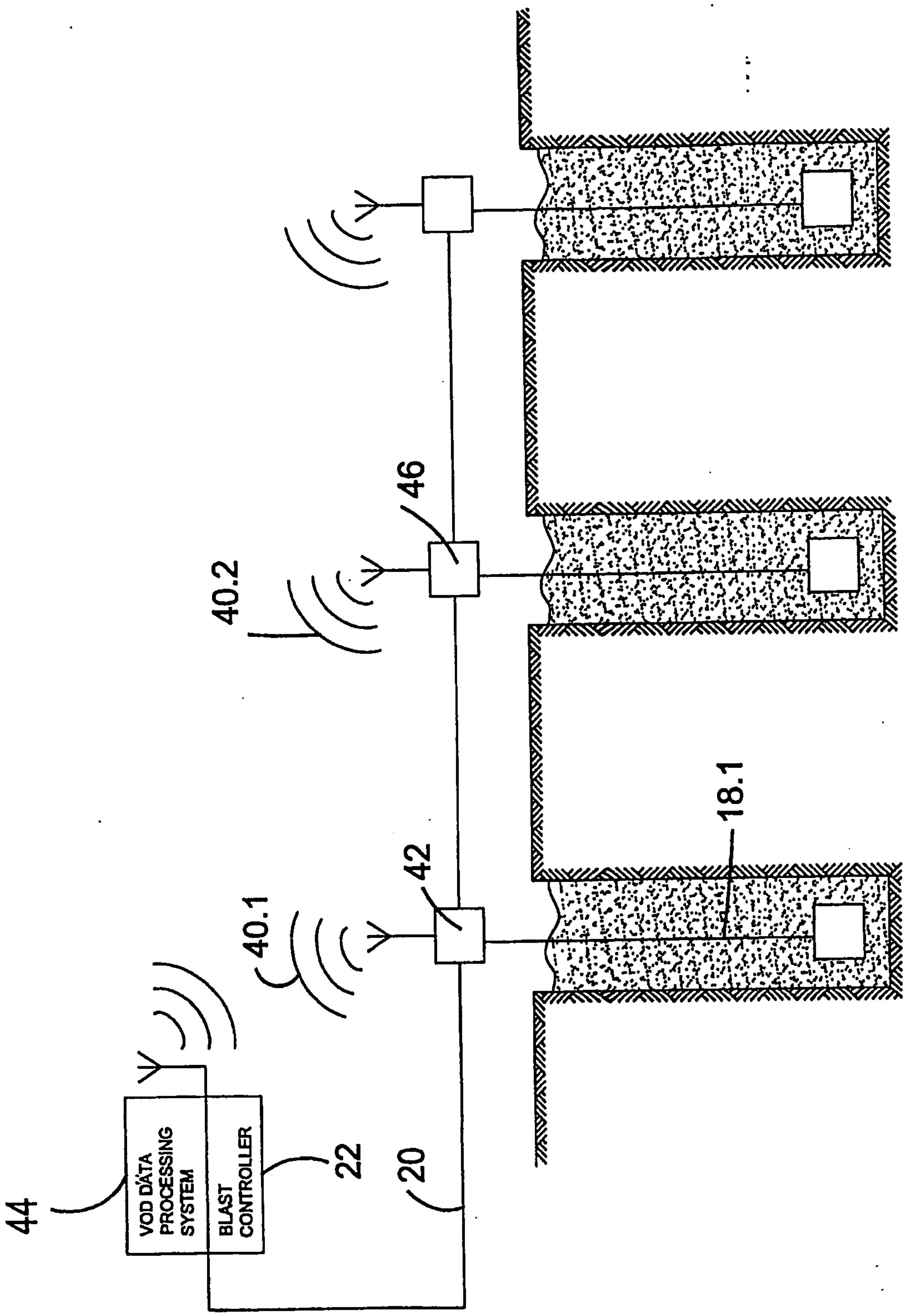

FIGURE 2

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Sheet 3

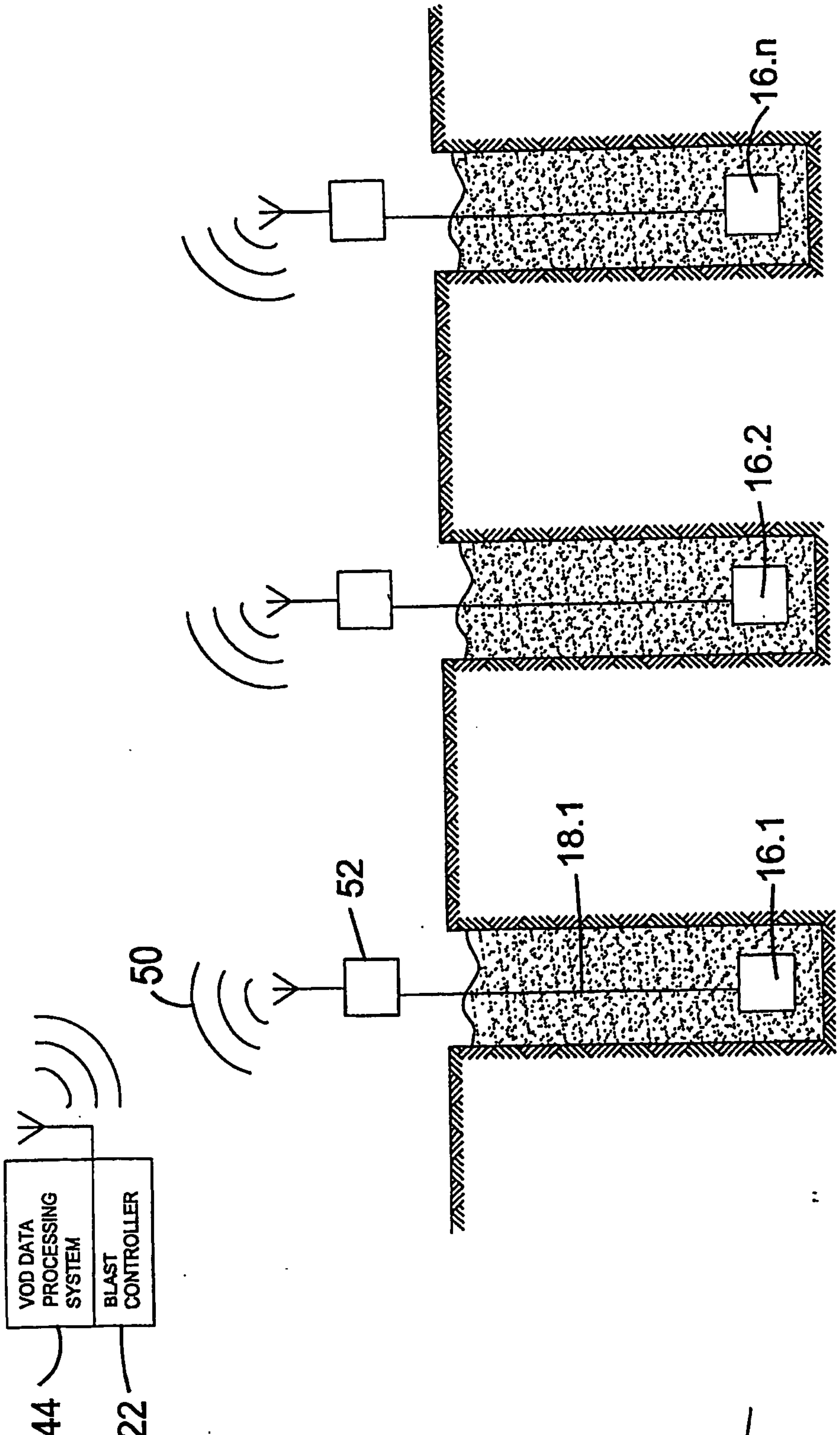

FIGURE 3

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2002/2513

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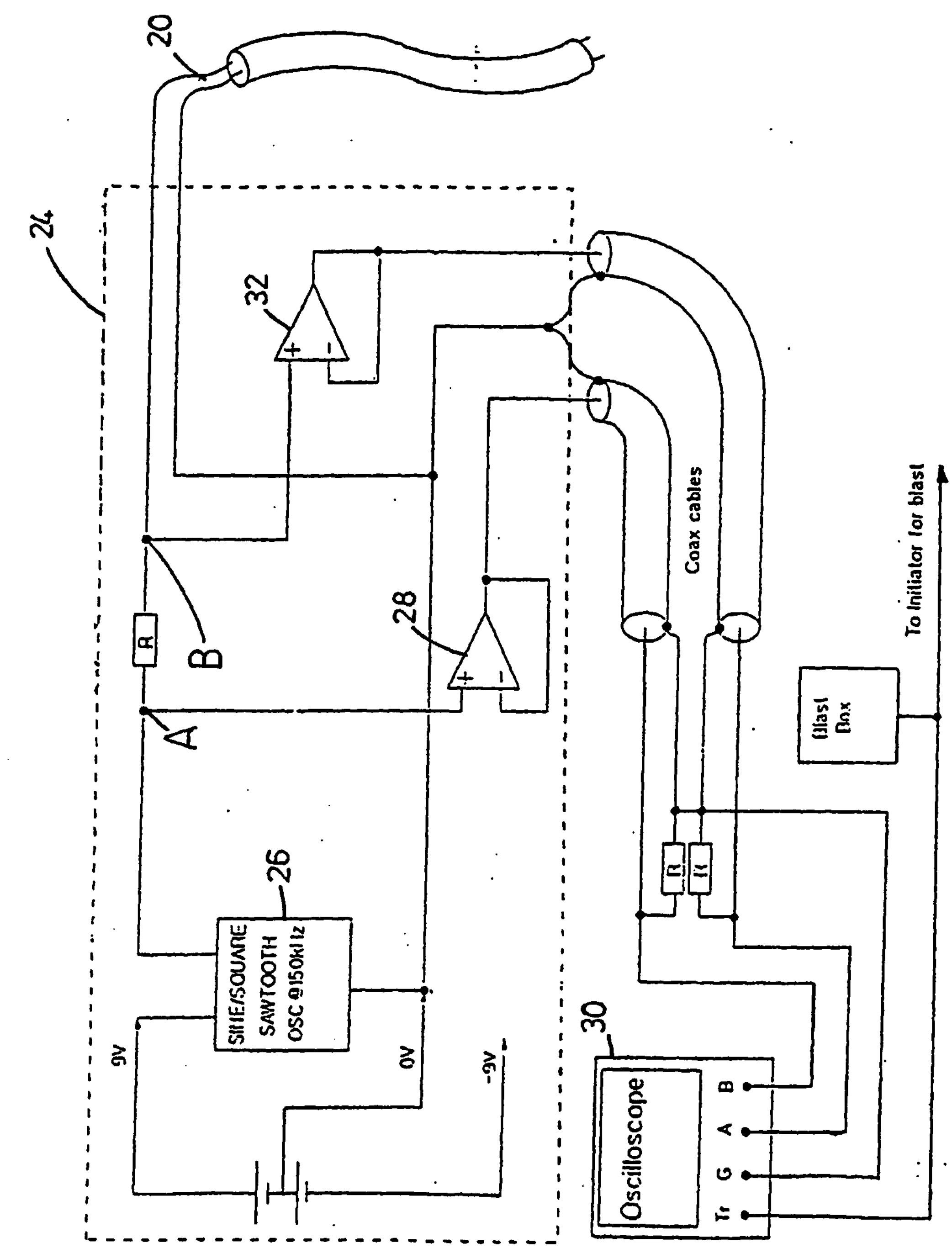

FIGURE 4

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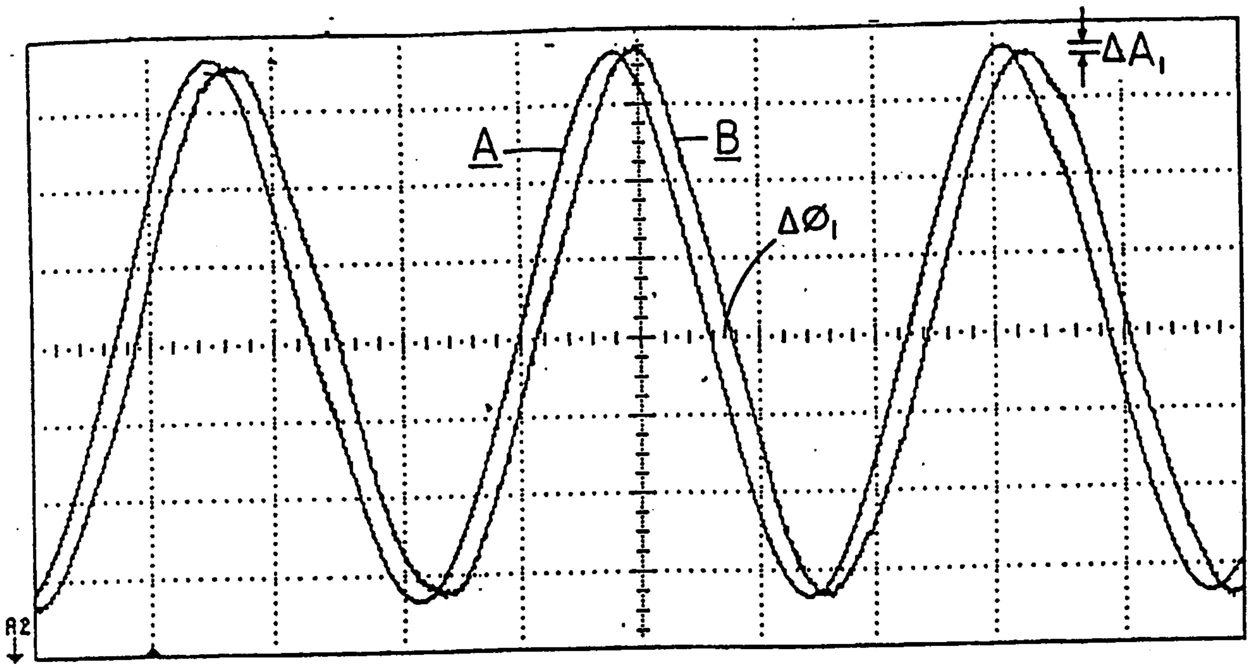

FIGURE 5

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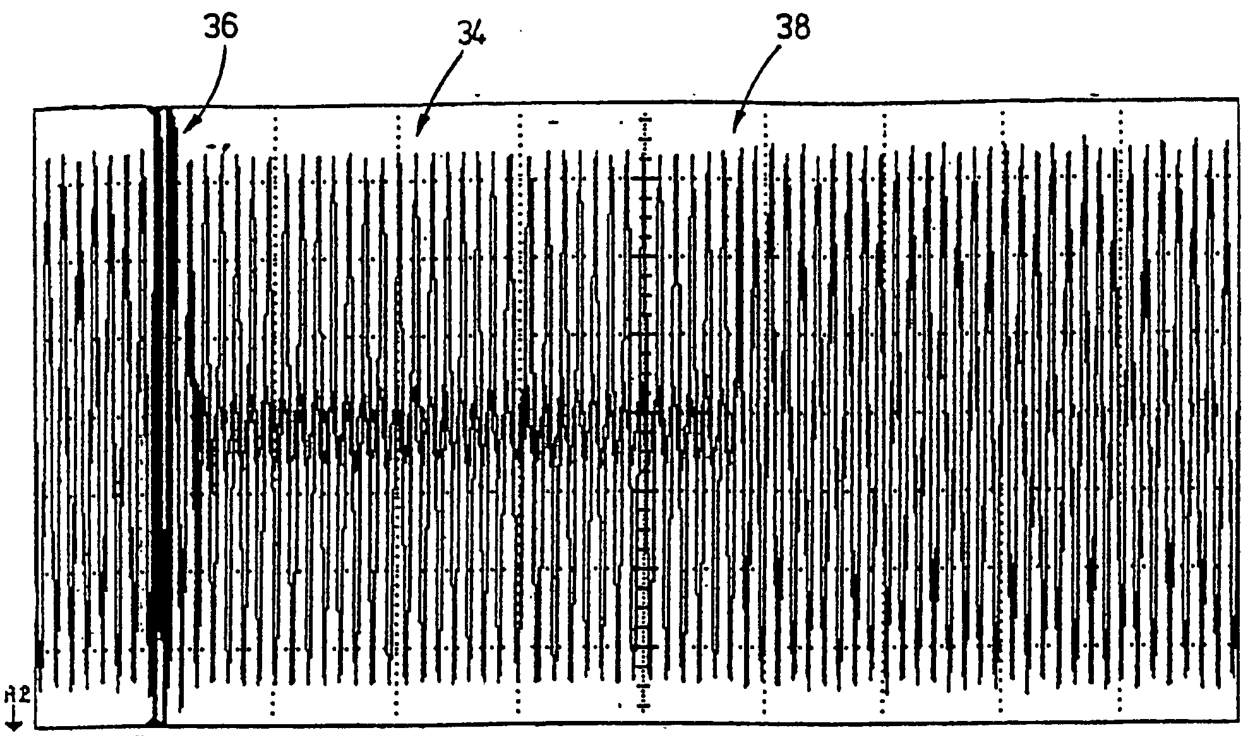

FIGURE 6

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Sheet 7

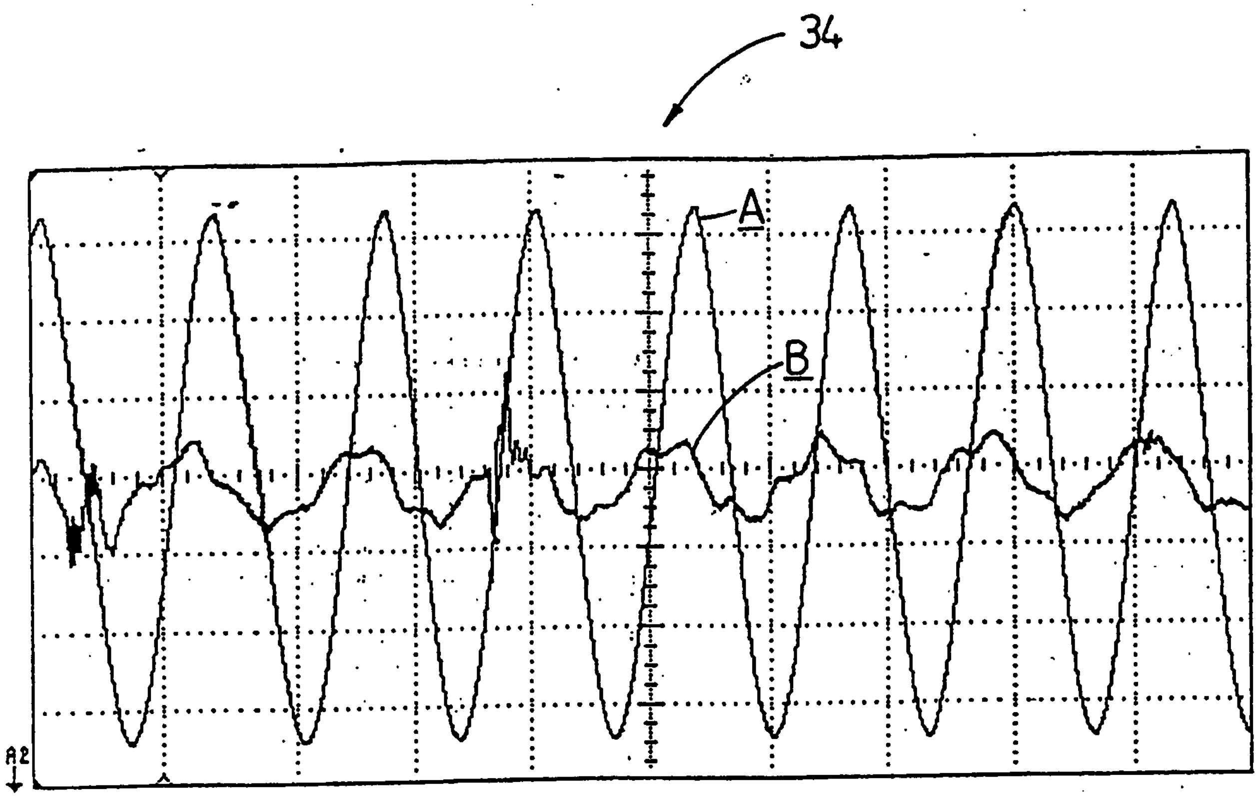

FIGURE 7

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Sheet 8

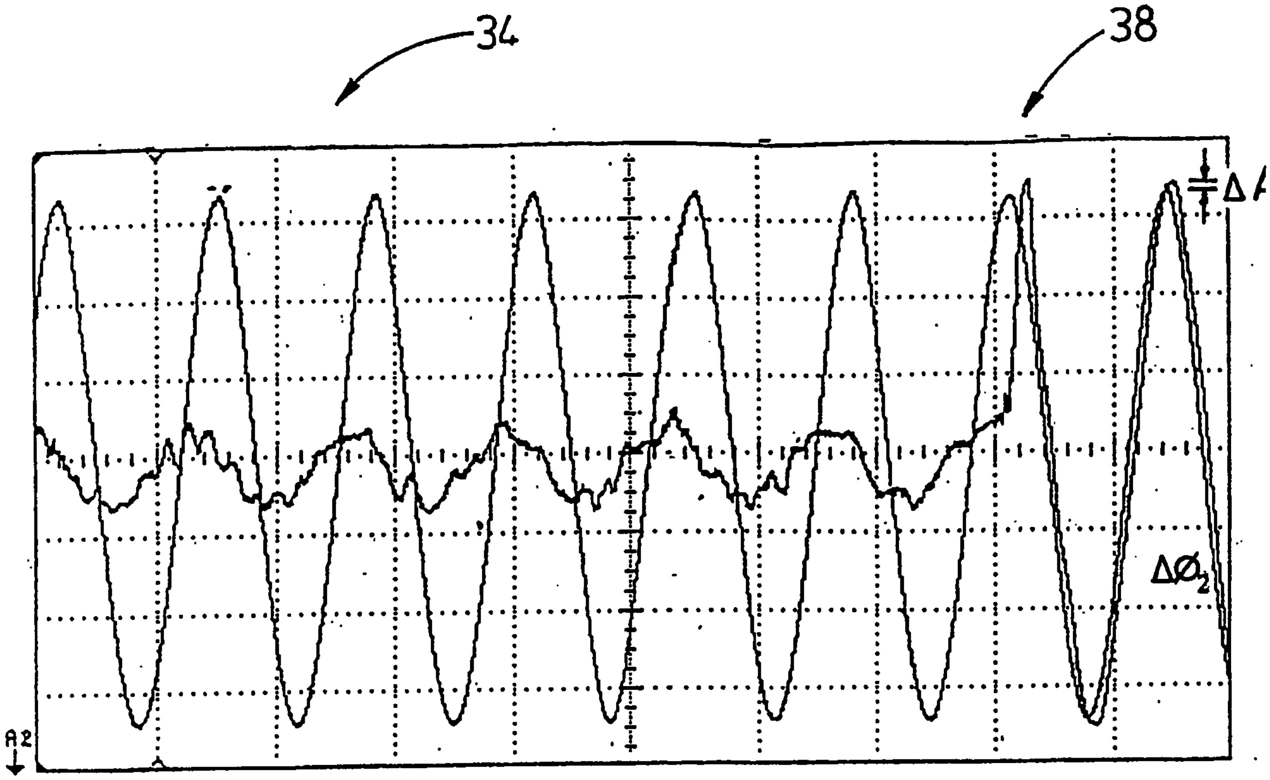

FIGURE 8